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Eric Carranza
Alex Konopliv
Mark Ryne

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109 - 8099

Send correspondence to:
Eric Carranza
Jet Propulsion Laboratory
Mail Stop 301 - 125J
4800 Oak Grove Drive
Pasadena, CA 91109 - 8099

Work #: (818) 354 - 4585
Fax #: (818) 393-6388
Eric.Carranza@jpl.nasa.gov

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ABSTRACT

The Lunar Prospector (LP) mission began on January 6, 1998, when the LP spacecraft was launched from Cape Canaveral, Florida. The objectives of the mission were to determine whether water ice exists at the lunar poles, generate a global compositional map of the lunar surface, detect lunar outgassing, and improve knowledge of the lunar magnetic and gravity fields. Orbit determination of LP performed at the Jet Propulsion Laboratory (JPL) is conducted as part of the principal science investigation of the lunar gravity field. This paper will describe the JPL effort in support of the LP Gravity Investigation. This support includes high precision orbit determination, gravity model validation, and data editing. A description of the mission and its trajectory will be provided first, followed by a discussion of the orbit determination estimation procedure and models. Accuracies will be examined in terms of orbit-to-orbit solution differences, as a function of oblateness model truncation, and inclination in the plane-of-sky. Long term predictions for several gravity fields will be compared to the reconstructed orbits to demonstrate the accuracy of the orbit determination and oblateness fields developed by the Principal Gravity Investigator.

The Lunar Prospector spacecraft was launched on January 6, 1998 aboard Lockheed Martin's three-stage, solid-fuel Athena II rocket. On January 15, 1998, the spin-stabilized LP was placed in a polar, near circular mapping orbit with a period of 118 minutes and an altitude of approximately 100 kilometers. This trajectory provided global coverage of the lunar surface for science collection every two weeks. During the one year primary mission, LP executed orbit correction and reorientation maneuvers to maintain its desired orbit and altitude. On December 19, 1998, the altitude of LP was reduces to an average of 40 kilometers to better determine the lunar gravity field in preparation for the extended mission. Lunar Prospector began its extended mission on January 29, 1999, when the spacecraft was lowered to an altitude of 30 kilometers above the lunar surface to obtain higher resolution mapping data. The LP mission is scheduled to end in July 1999.

Orbit determination for LP is performed using S-band, two-way Doppler and Sequential Range Assembly (SRA) data collected from Deep Space Network (DSN) 26 meter and 34 meter diameter tracking stations. Near continuous high-rate tracking is scheduled for the entire primary mission with interruptions lasting as long as 45 minutes per orbit as a result of occultation by the Moon. Due to their high volume, tracking data are compressed to a 10 second sample rate and invalid data are removed to reduce processing time. Corrections to the data include removal of the spin induced Doppler bias, per track station range calibration errors, and station dependent processing errors. High fidelity troposphere and ionosphere calibrations are also employed.

The orbit determination process solves the following set of estimated parameters: spacecraft state, solar radiation pressure coefficients, two-way Doppler biases, and SRA biases. Each set of solutions is usually determined by processing a two-day data arc; orbit correction maneuvers, reorientation maneuvers, and trimming Lunar Prospector's spin rate cause some data arcs to be longer and some data arcs to be shorter than two days. These maneuvers and spin rate trims are not modeled when processing a data arc; instead, data arcs end just before and begin just after such events occur to avoid corrupting the gravity field with unmodeled errors. A relatively simple estimation model is used because the trajectory perturbations are well characterized -- simple spacecraft structure, no out gassing or momentum wheel dumps, and a fixed solar pressure cross section. Six gravity perturbation models are used in determining the orbit of Prospector. They are the newtonian point-mass model, the relativity model, the direct and indirect oblateness models, the tide model, and the solar radiation pressure model. The olbateness model for the Moon was updated every two months by the Gravity Principal Investigator during the primary mission based on historical and LP data. Two-way tracking data is generally weighted at 1 mm/sec for Doppler and 2 meters for SRA.

The orbit determination accuracies are determined for the latest 100th degree gravity model (LP100J) for both the nominal and extended mission. Accuracies are determined by comparing one orbit overlap between adjacent solutions. For the nominal mission, results indicate a typical radial, cross-track (out-of-orbit plane), and along-track orbit errors of 1, 20, and 20 meters, respectively.

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